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(54) **PROTECTION OF LITHOGRAPHIC COMPONENTS FROM PARTICLE CONTAMINATION**

TEILCHENKONTAMINATIONSSCHUTZ FÜR LITHOGRAPHISCHE KOMPONENTEN

PROTECTION DE COMPOSANTS LITHOGRAPHIQUES CONTRE LA CONTAMINATION PAR DES PARTICULES

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Description

BACKGROUND OF THE INVENTION

[0001] This invention pertains generally to method and apparatus for preventing surface contamination by deposition of particulate matter and more particularly to preventing deposition of particulate matter onto lithographic components such as reticles (masks) and wafers during lithographic use, fabrication, inspection, repair, handling and storage.

[0002] The ability to produce high quality microelectronic devices and reduce yield losses is strongly dependent upon maintaining the surfaces substantially defect-free. This is particularly true as design rules drive integrated circuits to finer feature size. Generally, surface defects can be related to particulate matter being deposited onto surfaces of reticles (masks) and wafer substrates during the various operations required to produce integrated circuits. The need to maintain these surfaces substantially free of particulate matter has long been recognized in the microelectronics industry and various schemes to do so have been proposed, such as those set forth in U.S. Patent Nos. 5,373,806 and 5,472,550. The former discloses the use of thermal energy, such as the use of radiant energy, RF, or resistance heating, to substantially eliminate electrostatic attraction as a mechanism for particle transport and deposition during gas phase processing. It describes a reactor having chamber with process gas inlet and outlet. The reactor is made of a quartz vessel having low thermal and electrical conductivity walls. The latter describes the use of the photophoretic effect to capture particles by projecting a laser beam inside the processing chamber along a trajectory that does not contact the substrate surface.

[0003] US 5 061 444 describes a system for reducing deposition of fluid-borne particles. Objects are protected against deposition of fluid-borne particles in a diameter range of from one-hundredth of a micron to several microns from a surfaces of these objects and fluid ajacent thereto such that the température of these surfaces is higher by not more than 10K than that of the adjacent fluid, to such an extent that the thermophoretic effect dominates the combined effects of Brownian motion and gravitational deposition of the particles in the boundary layer flow. Highly advanced articles of manufacture are produced when those surfaces are changed structurally, such as during manufacture of integrated circuits, while the thermophoretic effect dominates the latter combined effects.

[0004] The concern about printable defects caused by particle deposition onto surfaces is of particular importance for the next generation of lithographies, including proximity x-ray lithography, direct-write and projection electron-beam lithography (SCALPEL), direct-write and projection ion-beam lithography, and extreme ultraviolet (radiation having a wavelength in the region of 3.5 - 15 nm) lithography (EUVL) which must provide for exclusion of particles with diameters greater than 0.01 μm. The situation is exacerbated by the fact that for a beam of high energy radiation (photons, electrons, ions, or atoms), such as used for the aforementioned advanced lithographies, a pellicle which is customarily employed to protect lithographic reticles (masks) from particle deposition cannot be used. The protective benefit provided by a protective membrane such as a pellicle is negated by its deleterious effect on the beam of high energy incident radiation. By way of example, a half micron thick Si film will reduce the light intensity at 13 nm by 60%, which is an intolerable reduction for most lithographic applications. Coupled with this is the difficulty of forming a durable pellicle consisting of a 1/2 μm Si film. In the case of electron lithography, the pellicle will absorb some of the electron current and, by inelastic scattering, introduce undesirable chromatic aberration into the electron beam and intolerable deviations in beam angle. While it is possible to produce organic polymeric materials in the proper thickness to form pellicles, they suffer from the disadvantage that they will decompose under the influence of high energy radiation, releasing volatile degradation products which, in turn, will coat optical surfaces and reduce their efficiency. Moreover, many of the advanced lithographic concepts must operate in a vacuum to reduce degradation of high energy radiation used for finer design rules consequently, the pellicle surface will be subjected to large changes in pressure (from 760 Torr to 5 x 10^{-4} Torr) over a surface area that may be as large as 100 cm^2 and thus, forces larger than a thin organic membrane pellicle can withstand will be generated.

[0005] Because of the importance of protecting lithographic surfaces, such as reticles, from deposition of particulate matter for next generation lithographies alternative protection schemes such as clean encapsulation of the exposure chamber, protective gas blankets, and in-situ cleaning of mask surfaces are being investigated. However, each of these alternative schemes has disadvantages and none have been developed to the point of application.

[0006] What is needed is a means to protect lithographic surfaces, such as those of the reticle and wafer, from particle deposition without comprising lithographic performance or contaminating lithographic optical elements. Moreover, in order to be useful in advanced lithographic applications it is necessary that the protecting means operate effectively in a sub-atmospheric pressure environment.

SUMMARY OF THE INVENTION

[0007] The present invention generally employs a physical phenomenon known as thermophoresis to protect lithographic surfaces from particle deposition and is particularly designed to operate in an environment where the pressure is substantially constant and can be

sub-atmospheric. Protection from particle deposition is afforded during lithographic use, fabrication, repair, handling, and storage without compromising lithographic performance or contaminating other lithographic components.

[0008] Thermophoresis can be a useful tool to overcome particle deposition onto surfaces because it is capable of overwhelming those mechanisms that lead to particle deposition such as: 1) electrostatic forces, 2) inertia, 3) Brownian motion, and 4) gravity. Thermophoretic forces operate to cause particles to be driven from regions of higher gas temperature to regions of lower gas temperature. However, it is known that the thermophoretic effect begins to become less effective as gas pressure is lowered, generally precluding its use where the surface to be protected is held at pressures below about 5 mTorr, as can be the case in many lithographic operations and, particularly for advanced lithographic concepts where operation in a vacuum is necessary to reduce attenuation of the radiation. According to the present invention, an apparatus for protecting a surface from particle deposition as defined by claims 1 and 5 is provided.

[0009] The present invention discloses a novel system that reduces particle deposition onto a surface by the use of thermophoresis, directed gas flow to isolate the surface from particles in the environment, orientation of the surface to eliminate gravitational deposition, and elimination of electric fields to protect the surface from electrostatic deposition. This invention is designed to provide particle protection in situations where the atmosphere is at substantially constant but sub-atmospheric pressure. However, because of the novel features of this invention, which have been disclosed above, the present invention can also be used in those applications where the surrounding atmosphere is at atmospheric pressure or above.

[0010] Because the system of the present invention functions in a manner similar to that of a conventional pellicle and for ease of description the system disclosed herein will be referred to hereinafter as a thermophoretic pellicle. While intended principally to provide protection to reticles (hereinafter the terms reticle and mask will be used interchangeably and synonymously) from particle deposition during operation of the lithographic process, it is contemplated that the thermophoretic pellicle can also provide protection for a reticle during fabrication, inspection and repair as well as storage, manual and robotic handling. Furthermore, the protection provided by the thermophoretic pellicle can extend to other lithographic components such as wafers, wafer chucks, filters, lenses, mirrors and reticle stages.

[0011] The thermophoretic pellicle, which is generally deployed in a chamber operating at a sub-atmospheric pressure, comprises an enclosure that surrounds a lithographic component having a surface needing protection from particle deposition, means for introducing a flow of gas into the enclosure, and at least one aperture that provides access to the surface being protected. Here, access is defined as permitting the entry and/or exit of a beam of radiation as well as the exit and control of the gas flow from the interior of the thermophoretic pellicle into the environment of the chamber containing the thermophoretic pellicle as well as admitting entry of mechanical devices, such as the probe of an atomic force microscope, into the thermophoretic pellicle. The surface of the lithographic component can be heated or, alternatively, the walls of the enclosure can be cooled to establish the required temperature gradient between the warmer surface of the lithographic component and the cooler walls of the enclosure that provides the desired thermophoretic force.

[0012] The present invention further provides protection from particle deposition onto a surface by employing a gas flow regime that directs particles away from the protected surface, substantially eliminates undesirable electrostatic deposition by the use of electrostatic shielding, and removes gravitational deposition by preferably positioning the surface being protected in a downward facing orientation.

[0013] In order to better understand and appreciate its nature and scope the present invention will now be described more fully hereinafter by way of various embodiments illustrative of the invention. This invention may, however, be embodied in many different forms and should not be construed as limited only to the embodiments set forth herein but as defined by the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Figure 1 shows an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The present invention discloses a system, the thermophoretic pellicle, designed to operate in an environment where the pressure is substantially constant, and can be sub-atmospheric, and employs a physical phenomenon known as thermophoresis to reduce the particle count on the surface of lithographic components by a factor of as much as 10^6 for particles having diameters as small as 0.01 μm by overwhelming those mechanisms that lead to particle deposition.

[0016] It is well known that surfaces can be protected from particle deposition by thermophoresis. By maintaining these surfaces at temperatures higher than their surroundings, particles are caused to migrate away from the heated surfaces. There are two critical features associated with thermophoresis generally and the thermophoretic pellicle of the present invention in particular: 1) a temperature gradient must be developed in the gas resident between the surface of the lithographic compo-

nent being protected from particle deposition and its surroundings; the surface of the lithographic component being warmer than its surroundings, and 2) the gas pressure must be sufficiently high to enable sufficient collisions between gas molecules and particles to develop a thermophoretic force. Thus, while thermophoresis vanishes in a perfect vacuum, pressures above about 100 mTorr are sufficient to establish, in most gases, a well defined temperature gradient and are preferred, however, useful thermophoretic protection can be established at pressures below about 100 mTorr, although with a lowered effectiveness.

[0017] As gas pressure decreases below about 100 mTorr, the continuum nature of the gas begins to break down and the gas is less able to maintain the desired temperature gradient needed to promote thermophoresis and, as a consequence, the effectiveness of thermophoretic protection is degraded. For those lithographic systems that require low overall system pressures for satisfactory performance, such as EUV lithography, direct-write and projection electron beam lithography (SCALPEL), direct-write and projection ion beam lithography, and vacuum materials processing, it is necessary to provide for a region of locally high pressure in the vicinity of the lithographic component being protected in order for thermophoresis to be effective, while simultaneously maintaining the general system environment at the necessary low operating pressure. In the present invention this is done by surrounding the lithographic component by an enclosure (the thermophoretic pellicle) that can be differentially pumped, thereby providing a region of locally higher pressure around the lithographic component to permit thermophoretic protection of the surface. The thermophoretic pellicle further provides for a gas flow that not only sweeps particles out of the pellicle but also eliminates the flow of particles and contaminants from the chamber environment outside the thermophoretic pellicle into the enclosure holding the protected surface. Moreover, particle deposition due to electrostatic attraction is substantially eliminated by eliminating electrical fields in the vicinity of the protected surface. Finally, particle deposition due to gravitational effects is eliminated by orienting the protected surface in a downwardly facing orientation.

[0018] Figure 1 shows a schematic representation of an embodiment of the thermophoretic pellicle **100** that comprises, in part, the present invention. Typically, thermophoretic pellicle **100** is contained within a system chamber **105** that establishes and maintains the general system operating pressure which is substantially constant but can range from atmospheric to sub-atmospheric or supra-atmospheric. In those instances where the general system operating pressure is sub-atmospheric as would be the case, for example for advanced lithography systems such as EUV lithography, direct write and projection electron beam lithography (SCALPEL), ion beam lithography, system chamber **105** is provided with pumping means to maintain a low operating pressure within the chamber. Chamber **105** can house a lithographic apparatus, or a reticle fabrication apparatus, or an inspection apparatus and establishes the operating environment in which the thermophoretic pellicle must operate. Here, the walls **110** of thermophoretic pellicle **100** enclose a reticle **120** whose surface **125** is to be protected from particle deposition, wherein surface **125** is oriented in a downwardly facing direction and is maintained at a higher temperature than walls **110**. Walls **110** can be made of any material but materials having high thermal conductivity such as silicon are preferred. Metals such as aluminum or copper are particularly preferred because of their high thermal conductivity. Moreover, the use of a metal for the walls of the thermophoretic pellicle eliminates one potential source of contamination, outgassing of the organic materials from which most conventional pellicles are typically made. It is also desirable to eliminate electrical fields from the vicinity of the reticle by constructing enclosure walls **110** from materials having high electrical conductivity, such as a metal, and to equalize any voltage difference between surface **125** and the enclosure walls **110,** for example, by grounding both or by simple electrical connection.

[0019] Thermophoretic pellicle **100** is also provided with at least one gas inlet means **130**, such as a valve, to permit flow of a gas into the interior of the enclosure. It will be appreciated that the gas be as free of particulate matter as possible in order to prevent extraneous particle deposition. Gas flow out of the interior of thermophoretic pellicle **100** is restricted by aperture **135** so as to maintain the pressure inside thermophoretic pellicle **100** at a value sufficient to provide effective thermophoretic protection. It is preferred that the pressure within thermophoretic pellicle **100** be at least about 30 mTorr, however, useful thermophoretic protection can be achieved where the pressure in the interior of thermophoretic pellicle **100** is as low as about 1 mTorr. Any gas can be used to maintain the pressure in the interior of the pellicle enclosure, however, a gas having a low molecular weight and high viscosity such as H_2, He, or Ne is preferred. For EUV applications Ar is preferred because it possesses a low cross-section for the absorption of EUV radiation, moreover, it is relatively easy to differentially pump.

[0020] Pellicle **100** is further provided with at least one aperture **135** that can be of any shape and which not only provides access to surface **125** for the entry and/ or exit of a beam of radiation, as well as mechanical devices, but also permits gas flow out of the thermophoretic pellicle, thereby acting as a gas conduction barrier allowing differential pumping of the enclosure. The gas flowing out of thermophoretic pellicle **100** through aperture **135** also acts to exclude from the interior of the thermophoretic pellicle particles and other contamination having its origin in system chamber **105**. The ability to differentially pump the thermophoretic pellicle, i.e., maintain an elevated pressure in the interior of the pel-

licle enclosure and over surface **125**, relative to the pressure within chamber **105**, makes it possible to employ the thermophoretic pellicle in applications where a low background pressure must be maintained within chamber **105**. The inventors have shown that in the configuration shown in Fig. 1, wherein the distance between the surface being protected and the proximate enclosure wall is ~ 1 cm, the temperature difference between the two is 10 K, the interior pressure is 30 mTorr, and the operating pressure in chamber **105** is < 5 mTorr, it is possible to reduce deposition of particles greater than 0.03 μm in diameter by a factor of about 10^6. It should be noted that the locations of the gas inlets and apertures, relative to the position of reticle **120,** are chosen such as to cause gas flow **127** to be substantially parallel to and away from surface **125,** thereby eliminating inertial deposition of particles onto the surface **125** of reticle **120**, and reducing entry of particles or other contaminants into thermophoretic pellicle **100**.

[0021] Reticle **120** can be mounted on any suitable mounting means **126**, such as an electrostatic chuck or an x-y stage. It is preferred that reticle **120** be mounted with surface **125** facing downward to eliminate particle deposition by gravitational settling. Mounting means **126** can be used as a source of radiative, convective, or conductive heat to heat reticle **120**, a radiative heat source can be used to heat the surface **125**, or a source of inductive heat can be provided, all in order to establish a temperature gradient between surface **125** and the walls **110** of pellicle **100**. Alternatively, walls **110** can be cooled by thermoelectric means or the use of flowing cooled fluids.

[0022] The degree of thermophoretic protection afforded a surface is a function of both the pressure of the gas within the thermophoretic pellicle and the temperature gradient existing between the walls and the surface being protected. The inventors have shown that the effectiveness of thermophoretic protection is determined, principally by the difference in temperature between the walls of the thermophoretic pellicle enclosure and the surface being protected and to a lesser extent by the absolute temperatures of the reticle and walls of the enclosure. It is preferred that there be a temperature gradient of at least about 1 K/cm between the surface of the reticle and the enclosure walls, wherein the surface of the reticle is warmer than the enclosure walls, coupled with a gas pressure within the thermophoretic pellicle of at least about 30 mTorr.

[0023] In the embodiment shown if Fig. 1 the thermophoretic pellicle is used to protect a reticle during the lithographic exposure operation and the pellicle is oriented such that the protected surface desirably faces in a downward direction. It will be appreciated by those skilled in the art that the thermophoretic pellicle disclosed here can also be used in many other lithographic operations, such as protection of a wafer during exposure, inspection, storage, and handling; protection of reticles during fabrication by such processes as sputtering of metallic and semiconducting layers, ion sputtering, thermal evaporation, or molecular beam epitaxy; and reticle inspection and repair. In many of these applications it is possible that the thermophoretic pellicle cannot be used in the orientation illustrated in Fig. 1, i. e., with the protected surface oriented in a downward facing direction. Providing the operating criteria set forth above are employed, the operation of the thermophoretic pellicle described herein can be independent of orientation of the protected surface, although a higher temperature gradient may be required if the protected surface faces in an upward facing orientation to compensate for increased gravitational deposition.

Claims

1. An apparatus for protecting a surface from particle deposition, comprising:

   (a) a thermophoretic pellicle (100) contained within a system chamber (105), said thermophoretic pellicle (100) having walls (110) comprising a material having high electrical and thermal conductivities, and provided with at least one gas inlet means (130) and at least one aperture (135) that controls the rate of outflow of a gas to maintain a region of locally high pressure within said thermophoretic pellicle (100) relative to a lower and sub-atmospheric pressure maintained in the system chamber (105) by pumping means;
   (b) a substrate (120) contained within said thermoghoretic pellicle (100), said substrate (120) having a surface (125) to be protected from particle deposition, wherein the at least one aperture (135) provides line of sight access to the surface (125) of the substrate (120) from the system chamber (105), and wherein the gas inlet means (130) and the at least one aperture (135) are located to provide a flow of gas substantially parallel to and away from the surface (125) of the substrate (120); and
   (c) means for establishing and maintaining a temperature gradient between the surface (125) of said substrate (120) and the walls (110) of said thermophoretic pellicle (100), wherein the surface (125) of said subtrate (120) is warmer than the enclosure walls (110).

2. The apparatus of claim 1, wherein the temperature gradient between the surface (125) of the substrate (120) and walls (110) of said thermophoretic pellicle (100) is at least about 5 °K/cm.

3. The apparatus of any preceding claim wherein the surface (125) being protected is oriented in a downward facing orientation.

4. The apparatus of any preceding claim further including means for eliminating any electric field between the front surface (125) of said substrate (120) and the walls (110) of said thermophoretic pellicle (100).

5. An apparatus for protecting a surface of a reticle from particle contamination in a low pressure lithographic system chamber (105), comprising:

(a) a thermophoretic pellicle (100) contained within the lithographic system chamber (105), said thermophoretic pellicle (100) having walls (110) comprising a material having high electrical and thermal conductivities, and provided with at least one gas inlet means (130) and at least one aperture (135) that controls the rate of outflow of a gas to maintain a region of locally high pressure within said thermophoretic pellicle (100), relative to a lower and sub-atmospheric pressure maintained in the system chamber (105) by pumping means;
(b) a reticle (120) contained within said thermophoretic pellicle (100), said reticle (120) having a front surface (125) to be protected from particle deposition and a back surface, wherein the back surface is disposed on a mounting means (126), and wherein the at least one aperture (135) provides line of sight access to the front surface (125) of said reticle (120) from the system chamber (105), and the gas inlet means (130) and the at least one aperture (135) are located to provide a flow of gas substantially parallel to and away from the front surface (125) of said reticle (120);
(c) means for eliminating any electric field between the front surface (125) of said reticle (120) and the walls (110) of said thermophoretic pellicle (100); and
(d) means for establishing a temperature gradient between the front surface (125) of said reticle (120) and the walls (110) of said thermophoretic pellicle (100), wherein the front surface (125) is warmer than the walls (110).

6. The apparatus of claim 5, wherein the mounting means (126) includes an electrostatic chuck or an x-y-z- stage.

7. The apparatus of claim 5 or 6, wherein the mounting means (126) provides a source of radiative, convective, or conductive heat.

8. The apparatus of any of claims 5 - 7, wherein the temperature gradient between the front surface (125) of said reticle (120) and the walls (110) of said thermophoretic pellicle (100) is at least about 5 °K/cm.

9. The apparatus of any preceding claim wherein the pressure within said thermophoretic pellicle (100) is greater than about 1 mTorr.

10. The apparatus of any preceding claim wherein the pressure within said thermophoretic pellicle (100) is at least about 30 mTorr.

11. The apparatus of any preceding claim wherein the pressure within said system chamber (105) is less than about 100 mTorr.

12. The apparatus of any preceding claim wherein the gas has a low molecular weight.

13. The apparatus of any preceding claim wherein the gas is H_2 or He.

14. The apparatus of any of claims 1-11 wherein the gas includes Ne, Ar, N_2, or air.

15. The apparatus of any preceding claim wherein the walls (110) of said thermophoretic pellicle (100) are made of a metal.

16. The apparatus of claim 15 wherein the metal is copper, aluminum, brass, molybdenum, or stainless steel.

17. The apparatus of claims 5-16 wherein the front surface (125) of said reticle (120) is oriented in a downward facing orientation.

Patentansprüche

1. Vorrichtung zum Schutz einer Oberfläche vor Partikelablagerung, mit

(a) einem thermophoretischen Film (100), der in einer Systemkammer (105) eingeschlossen ist, wobei der thermophoretische Film (100) Wände (110) hat, die ein Material mit hohen elektrischen und Wärmeleitfähigkeiten aufweisen, und mit mindestens einer Gaseinlasseinrichtung (130) und mindestens einer Öffnung (135) versehen ist, die die Ausströmgeschwindigkeit eines Gases regelt, um einen Bereich mit lokal hohem Druck innerhalb des thermophoretischen Films (100) relativ zu einen niedrigeren Unterdruck aufrechtzuerhalten, der durch eine Pumpeinrichtung in der Systemkammer (105) aufrechterhalten wird,
(b) einem Substrat (120), das in dem thermophoretischen Film (100) eingeschlossen ist und das eine vor Partikelablagerung zu schützende Oberfläche (125) hat, wobei die mindestens eine Öffnung (135) Sichtlinienzugang zu der

Oberfläche (125) des Substrats (120) von der Systemkammer (105) her ermöglicht und wobei die Gaseinlasseinrichtung (130) und die mindestens eine Öffnung (135) so angeordnet sind, dass sie eine Gasströmung im wesentlichen parallel zu und weg von der Oberfläche (125) des Substrats (120) ermöglichen, und

(c) einer Einrichtung zum Herstellen und Aufrechterhalten eines Temperaturgefälles zwischen der Oberfläche (125) des Substrats (120) und den Wänden (110) des thermophoretischen Films (100), wobei die Oberfläche (125) des Substrats (120) wärmer als die Einhüll-Wände (110) ist.

2. Vorrichtung nach Anspruch 1, bei der das Temperaturgefälle zwischen der Oberfläche (125) des Substrats (120) und Wänden (110) des thermophoretischen Films (100) mindestens ungefähr 5 °K/cm beträgt.

3. Vorrichtung nach einem der vorhergehenden Ansprüche, bei der die Oberfläche (125), die geschützt wird, in einer nach unten gerichteteten Orientierung orientiert ist.

4. Vorrichtung nach einem der vorhergehenden Ansprüche, die weiterhin eine Einrichtung zum Beseitigen irgendeines elektrischen Feldes zwischen der Vorderseite (125) des Substrats (120) und den Wänden (110) des thermophoretischen Films (100) enthält.

5. Vorrichtung zum Schutz einer Oberfläche eines Retikulums vor Partikelverunreinigung in einer Niederdruck-Lithografie-Systemkammer (105), mit

(a) einem thermophoretischen Film (100), der in der Lithografie-Systemkammer (105) eingeschlossen ist, wobei der thermophoretische Film (100) Wände (110) hat, die ein Material mit hohen elektrischen und Wärmeleitfähigkeiten aufweisen, und mit mindestens einer Gaseinlasseinrichtung (130) und mindestens einer Öffnung (135) versehen ist, die die Ausströmgeschwindigkeit eines Gases regelt, um einen Bereich mit lokal hohem Druck innerhalb des thermophoretischen Films (100) relativ zu einen niedrigeren Unterdruck aufrechtzuerhalten, der durch eine Pumpeinrichtung in der Systemkammer (105) aufrechterhalten wird,

(b) einem Retikulum (120), das in dem thermophoretischen Film (100) eingeschlossen ist und das eine vor Partikelablagerung zu schützende Vorderseite (125) und eine Rückseite hat, wobei die Rückseite auf einer Befestigungseinrichtung (126) angeordnet ist und wobei die mindestens eine Öffnung (135) Sichtlinienzugang zu der Vorderseite (125) des Retikulums (120) von der Systemkammer (105) her ermöglicht und die Gaseinlasseinrichtung (130) und die mindestens eine Öffnung (135) so angeordnet sind, dass sie eine Gasströmung im wesentlichen parallel zu und weg von der Vorderseite (125) des Retikulums (120) ermöglichen,

(c) einer Einrichtung zum Beseitigen irgendeines elektrischen Feldes zwischen der Vorderseite (125) des Retikulums (120) und den Wänden (110) des thermophoretischen Films (100), und

(d) einer Einrichtung zum Herstellen eines Temperaturgefälles zwischen der Vorderseite (125) des Retikulums (120) und den Wänden (110) des thermophoretischen Films (100), wobei die Vorderseite (125) wärmer als die Wände (110) ist.

6. Vorrichtung nach Anspruch 5, bei der die Befestigungseinrichtung (126) eine elektrostatische Spannvorrichtung oder einen x-y-z-Tisch enthält.

7. Vorrichtung nach Anspruch 5 oder 6, bei der die Befestigungseinrichtung (126) eine Quelle von Strahlungs-, Konvektions- oder Leitwärme bereitstellt.

8. Vorrichtung nach einem der Ansprüche 5 bis 7, bei der das Temperaturgefälle zwischen der Vorderseite (125) des Retikulums (120) und den Wänden (110) des thermophoretischen Films (100) mindestens ungefähr 5 °K/cm beträgt.

9. Vorrichtung nach einem der vorhergehenden Ansprüche, bei der der Druck innerhalb des thermophoretischen Films (100) größer als ungefähr 1 mTorr ist.

10. Vorrichtung nach einem der vorhergehenden Ansprüche, bei der der Druck innerhalb des thermophoretischen Films (100) mindestens ungefähr 30 mTorr beträgt.

11. Vorrichtung nach einem der vorhergehenden Ansprüche, bei der der Druck innerhalb der Systemkammer (105) kleiner als ungefähr 100 mTorr ist.

12. Vorrichtung nach einem der vorhergehenden Ansprüche, bei der das Gas ein niedriges Molekulargewicht hat.

13. Vorrichtung nach einem der vorhergehenden Ansprüche, bei der das Gas H_2 oder He ist.

14. Vorrichtung nach einem der Ansprüche 1 bis 11, bei der das Gas Ne, Ar, N_2 oder Luft enthält.

15. Vorrichtung nach einem der vorhergehenden An-

sprüche, bei der die Wände (110) des thermophoretischen Films (100) aus Metall bestehen.

16. Vorrichtung nach Anspruch 15, bei der das Metall Kupfer, Aluminium, Messing, Molybdän oder rostfreier Stahl ist.

17. Vorrichtung nach einem der Ansprüche 5 bis 16, bei der die Vorderseite (125) des Retikulums (120) in einer nach unten gerichteteten Orientierung orientiert ist.

Revendications

1. Appareil destiné à protéger une surface contre un dépôt de particules, comprenant :

   (a) une pellicule thermophorétique (100) placée à l'intérieur d'une chambre de système (105), ladite pellicule thermophorétique (100) ayant des parois (110) comprenant un matériau ayant des conductivités thermique et électrique élevées et étant pourvue d'au moins un moyen d'arrivée de gaz (130) et d'au moins une ouverture (135) qui commande le débit de sortie d'un gaz de façon à maintenir une zone de pression localement élevée à l'intérieur de ladite pellicule thermophorétique (100) par rapport à une pression inférieure et négative entretenue dans la chambre de système (105) par des moyens de pompage ;
   (b) un substrat (120) placé à l'intérieur de ladite pellicule thermophorétique (100), ledit substrat (120) ayant une surface (12) à protéger contre un dépôt de particules, dans lequel ladite au moins une ouverture (135) définit un accès en ligne droite à la surface (125) du substrat (120) depuis la chambre de système (105), et dans lequel les moyens d'arrivée de gaz (130) et ladite au moins une ouverture (135) sont placés de façon à permettre un écoulement de gaz sensiblement parallèle à et éloigné de la surface (125) du substrat (120) ; et
   (c) des moyens destinés à établir et à maintenir un gradient de température entre la surface (125) dudit substrat (120) et les parois (110) de ladite pellicule thermophorétique (100), la surface (125) dudit substrat (120) étant plus chaude que les parois d'enveloppe (110).

2. Appareil selon la revendication 1, dans lequel le gradient de température entre la surface (125) du substrat (120) et les parois (110) de ladite pellicule thermophorétique (100) est d'au moins 5°K/cm environ.

3. Appareil selon l'une quelconque des revendications précédentes, dans lequel la surface (125) à protéger est orientée dans une direction tournée vers le bas.

4. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre des moyens destinés à éliminer tout champ électrique entre la surface avant (125) dudit substrat (120) et les parois (110) de ladite pellicule thermophorétique (100).

5. Appareil destiné à protéger une surface de réticule contre la contamination par des particules dans une chambre de système lithographique (105) à basse pression, comprenant :

   (a) une pellicule thermophorétique (100) placée à l'intérieur de la chambre de système lithographique (105), ladite pellicule thermophorétique (100) ayant des parois (110) comprenant un matériau ayant des conductivités thermique et électrique élevées et étant pourvue d'au moins un moyen d'arrivée de gaz (130) et d'au moins une ouverture (135) qui commande le débit de sortie d'un gaz de façon à maintenir une zone de pression localement élevée à l'intérieure de ladite pellicule thermophorétique (100) par rapport à une pression inférieure et négative entretenue dans la chambre de système (105) par des moyens de pompage ;
   (b) un réticule (120) placé à l'intérieur de ladite pellicule thermophorétique (100), ledit réticule (120) ayant une surface avant (125) à protéger contre un dépôt de particules ainsi qu'une surface arrière, dans lequel la surface arrière est disposée sur des moyens de montage (126), et dans lequel ladite au moins une ouverture (135) définit un accès en ligne droite à la surface avant (125) dudit réticule (120) depuis la chambre de système (105), et les moyens d'arrivée de gaz (130) ainsi que ladite au moins une ouverture (135) sont placés de façon à permettre un écoulement de gaz sensiblement parallèle à et éloigné de la surface avant (125) dudit réticule (120) ;
   (c) des moyens destinés à éliminer tout champ électrique entre la surface avant (125) dudit réticule (120) et les parois (110) de ladite pellicule thermophorétique (100) ; et
   (d) des moyens destinés à établir un gradient de température entre la surface avant (125) dudit réticule (120) et les parois (110) de ladite pellicule thermophorétique (100), la surface avant (125) étant plus chaude que les parois (110).

6. Appareil selon la revendication 5, dans lequel les moyens de montage (126) comprennent un plateau de fixation électrostatique ou un plateau x-y-z.

7. Appareil selon la revendication 5 ou 6, dans lequel les moyens de montage (126) comprennent une source de chaleur par radiation, par convection ou par conduction.

8. Appareil selon l'une quelconque des revndications 5 à 7, dans lequel le gradient de température entre la surface avant (125) dudit réticule (120) et les parois (110) de ladite pellicule thermophorétique (100) est d'au moins 5°K/cm.

9. Appareil selon l'une quelconque des revendications précédentes, dans lequel la pression à l'intérieur de ladite pellicule thermophorétique (100) est supérieure à environ 1mTorr.

10. Appareil selon l'une quelconque des revendications précédentes, dans lequel la pression à l'intérieur de ladite pellicule thermophorétique (100) est d'au moins 30 mTorr environ.

11. Appareil selon l'une quelconque des revendications précédentes, dans lequel la pression à l'intérieur de ladite chambre de système (105) est inférieure à 100 mTorr environ.

12. Appareil selon l'une quelconque des revendications précédentes, dans lequel le gaz a un faible poids moléculaire.

13. Appareil selon l'une quelconque des revendications précédentes, dans lequel le gaz est du H_2 ou du He.

14. Appareil selon l'une quelconque des revendications 1 à 11, dans lequel le gaz comprend du Ne, du Ar, du N_2 ou de l'air.

15. Appareil selon l'une quelconque des revendications précédentes, dans lequel les parois (110) de ladite pellicule thermophorétique (100) sont réalisées en un métal.

16. Appareil selon la revendication 15, dans lequel le métal est du cuivre, de l'aluminium, du laiton, du molybdène ou de l'acier inoxydable.

17. Appareil selon les revendications 5 à 16, dans lequel la surface avant (125) dudit réticule (120) est orientée dans une direction tournée vers le bas.

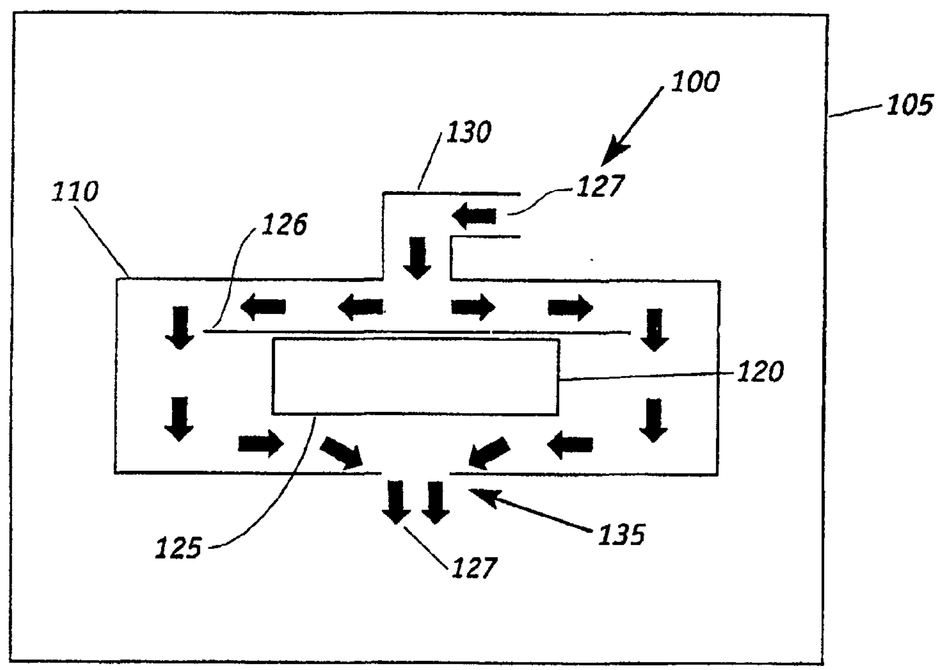

FIG. 1